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Federal Aviation Administration
Washington, D. C.

August 1973

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Report No. FAA-RD-73-116

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Final Report

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DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

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TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-RD-73-116		

4. Title and Subtitle
A Potential Design Window for Supersonic Overflight Based on the Perceived Level PLdB And Glass Damage Probability of Sonic Booms

5. Report Date
August 1973

6. Performing Organization Code

7. Author(s)
Thomas H. Higgins and Larry K. Carpenter

8. Performing Organization Report No.

9. Performing Organization Name and Address
Department of Transportation
Federal Aviation Administration
System Research and Development Service
Washington D. C. 20590

10. Work Unit No.
202 554 015

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
Department of Transportation
Federal Aviation Administration
System Research and Development Service
Washington, D. C. 20590

13. Type of Report and Period Covered
Final Report

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A potential design window for supersonic overflight based on the perceived level (PLdB) and glass damage probability of sonic booms is outlined.

The evaluation of a simple operational method of estimating the perceived level (PLdB) of sonic booms:

$$\mathrm{PLdB} = 55 + 20 \log_{10} \frac{\Delta P \text{ (psf)}}{\tau \text{ (sec)}}$$

is discussed and compared with the Fourier transform computer program calculations of Pease based on the theory of Zepler and Harel. The resulting estimated perceived levels are in good agreement i.e., within 1 to 2 PLdB of each other in the important potential certification or design window that is in the 90 to 100 PLdB range. These perceived levels are shown to be acceptable to 95 to 100 percent of the people exposed to them.

The levels estimated using the method of May vary considerably with the levels determined by the other 2 methods, previously discussed.

17. Key Words
Overpressure
Rise Time
Acceptability
Perceived Level (PLdB)

18. Distribution Statement
Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	24	

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I. INTRODUCTION

Man's ability to fly aircraft faster than the speed of sound generated one of the most controversial and most misunderstood phenomena, namely, the sonic boom. The sonic boom is a major environmental effect of supersonic flight that sets it apart from other aircraft operations. As a result, the supersonic era generated a great volume of research on the sonic boom and its effects. Very significant accomplishments have occurred in technical matters dealing with generation, prediction, propagation, simulation of the sonic boom and its effect on man and his environment.

A notice of proposed rule making was issued in April of 1970 (Ref. 1) to afford the public protection from civil aircraft sonic boom. On March 23, 1973, an amendment (Ref. 2) to the Federal Aviation Act of 1958 was issued and, in brief, the rule limits the speed of civil aircraft operated within the United States territorial land or waters to a maximum which preclude the generation of a sonic boom which will touch these areas. Subject to authorization by the Administrator, exceptions to the amendment are left open for research.

A design window for civil supersonic aircraft is required and the following is presented as a start on its definition.

Design criteria for the U. S. Civil Supersonic Transport focused on peak overpressure as it was readily predictable using Whitham's (Ref. 13) equation. Due to the results of community reaction studies such as Oklahoma City and simulator studies investigating human reaction to sonic booms, it is now known that not only is the maximum peak overpressure (ΔP) an important parameter, but equally important is the rise time (τ) relationship with overpressure ($\Delta P/\tau$) or rate of on-set of the maximum peak overpressure. The rise time is the time required to change from ambient pressure to maximum peak overpressure. Designing towards the right combination of overpressure and rise time would produce a sonic boom in audible ranges acceptable to the public. If acceptable sonic boom characteristics were established, then designers of future civil supersonic aircraft could meet such standards. Therefore, the need is to begin and continue psychophysical work in areas that would determine acceptability limits for sonic booms as well as aerodynamic work that would control both the rise time and overpressure.

II. BACKGROUND

Based on the 1965 work of Zepler and Harel (Ref. 3) a memorandum (Ref. 4) was written February 21, 1968, and discussed with the Operations and Engineering personnel of the U.S. Supersonic Transport (SST) Development Office urging the adoption of a Sonic Boom Index = k ΔP (PSF), /τ(SEC) (Ref. 4), to advance the state-of-the-art in sonic boom research and to communicate with aircraft designers the importance of another sonic boom signature parameter in addition to overpressure, i.e., the interaction of rise-time and overpressure.

It was believed at that time that rise-time τ in the above equation was of equal importance as overpressure, i.e. ΔP in affecting human reaction to sonic booms. This memorandum was followed by papers (Ref. 5,6,7) outlining the relationship between overpressure/rise-time and human reaction expressed in Figure 1 and subsequently adding the perceived noise levels based on the Edwards Air Force Base (AFB) Sonic Boom test results. This was possible as a jury of Edwards AFB subjects found sonic booms with an average overpressure of 1.69 psf to be equivalent to the 105 PNdB flyover noise of a KC-135 aircraft (Ref. 8).

Convinced that average rise-time was equally important as average overpressure regarding the judged noise level the next step was to determine the rise-time associated with this judgement. A rise-time of 0.005 seconds was found to be appropriate based on available Edwards AFB test data. The noise level for other combinations of ΔP/τ could then be calculated based on the conviction that a doubling of overpressure or a halving of rise-time increased the perceived level by 6 PNdB.

These ideas and References 5,6,7 were subsequently presented to Mr. John Large of the Boeing Acoustics Staff with the objective of entering considerations of sonic boom overpressure/rise-time into U.S. SST design trades. Mr. Large now at the Institute of Sound and Vibration through the work of May (Ref. 19) has supplied additional evidence to support the validity of these ideas.

It only remained to quantify this relationship as shown subsequently in Equation two (2) to arrive at a very quick and simple approach to determining the perceived level of a sonic boom when overpressure and rise-time are known. The most important idea is that the Boom Index and Equation 2 hold the key to unlocking the required design criteria for supersonic aircraft.

The general formula for estimating the perceived levels of a sonic boom was derived as follows:

> The Edwards AFB sonic boom test results (Ref. 8) indicated that a sonic boom doubled in perceived noise level (PNL) for each 6 PNdB increase as compared to aircraft noise which requires 10 PNdB. Therefore, the PNL of a sonic boom increases as a function of 20 Log_{10} X as when X doubles or is 2 then the PNL increases by 6 PNdB (20 times .3).

The subjects rating the sonic booms at Edwards judged the noise level of a boom averaging 1.69 psf overpressure (ΔP) and rise-time (τ) of 0.005 seconds as being equivalent to aircraft flyover noise of 105 PNdB. Expressing this information mathematically as a linear equation, we have:

$$\text{PNdB} = k + 20 \text{ Log}_{10} \Delta P/\tau \qquad (1)$$

$$105 = k + 20 \text{ Log}_{10} 1.69/.005$$

$$105 = k + 20 \text{ Log}_{10} 338$$

$$105 = k + 20 \ (2.5)$$

$$k = 105 - 50$$

$$k = 55$$

The general formula for estimating the perceived level of a sonic boom is, therefore:

$$\text{Perceived Level (PLdB)} = 55 + 20 \text{ Log}_{10} \Delta P \text{ (PSF)}/\tau \text{(SEC)} \qquad (2)$$

Equation 2 has been plotted in Figure 1 employing an overpressure versus rise-time plot which yields the appropriate perceived level in decibels, PLdB.

Examination of the psychophysical work completed during the last 30 years (Ref. 9) discloses that the annoyance and/or loudness judgements of subjects are very similar in the frequency range of sonic booms generated by high flying supersonic aircraft which are for the most part below 1000 Hz. Therefore, the formula is equally good in measuring and predicting human annoyance or loudness reactions to sonic boom.

For this reason it is proposed that the predictive equation for sonic boom be labeled PLdB the perceived level in decibels as outlined in the work of S.S. Stevens (Ref. 9). The PLdB Level may then be construed to be a measure of how people react to sonic booms. The Perceived Level (PLdB) measure has another advantage in that it solves a largely semantic problem. That is how can one have an acceptable perceived noise level when by definition "noise" is "unwanted sound". As a result, an operating agency has the real problem plus a pseudo problem of trying to find an acceptable level of something that is by definition "unwanted".

To eliminate this problem in communications, it is proposed that the terminology perceived level (PLdB) be adopted by the scientific community. This is borne out by the test findings that there are indeed perceived levels, PLdB, of sonic booms which are acceptable to 100 percent of the people exposed to them.

By studying the above equation, it becomes apparent that a possible design window may be opened if the right overpressure and rise time conditions for acceptable sonic boom perceived levels are met.

Equation 2 can be easily rewritten to accomodate other units of overpressure measurement. For example:

$$\text{Perceived Level (PLdB)} = 21 + 20 \text{ Log}_{10} \Delta P \ (N/M^2)/\tau \text{ (SEC)} \tag{3}$$

$$\text{Perceived Level (PLdB)} = 1 + 20 \text{ Log}_{10} \Delta P \ (\mu B)/\tau \text{ (SEC)} \tag{4}$$

Figure 2 presents a comparison of the results obtained by using Equations (2), (3), or (4) which are identical but use different units of measurement, i.e., psf, N/M^2 and uB respectively with the Fourier transform computer program calculations of Pease (Ref. 20) based on the theory of Zepler and Harel (Ref. 3).

The resulting estimated perceived levels are in good agreement, i.e. within 1 or 2 PLdB of each other in the important potential certification or design window that is in the 90 to 100 PLdB range. These perceived levels are shown subsequently to be acceptable to 95 to 100 percent of the people exposed to them.

Figure 2 also shows that the levels estimated using the method of May (Ref. 19) vary considerably with the levels determined by the other two methods.

III. CURRENT STATE-OF-THE-ART

To begin to outline the potential design ballpark, the rise-time and overpressure values presently attained by today's aircraft, SR-71 Data (Ref. 10), are presented in Figure 3. Operating at 70,000 feet and a Mach Number of 3.0, the average rise-time is 0.010 seconds and the average overpressure is approximately 1.0 pounds per square foot. Using the SR-71 data of Figure 3 and Equation 2, developed herein, it is found that the perceived levels range from a high of approximately 115 PLdB to a low of around 80 PLdB with an average of 95 PLdB. The question that remains is what is an acceptable sonic boom perceived level? Or, in other words, how does one define a sonic boom which is acceptable to humans?

Some past test data (Ref. 11), begins to answer this question. The study employed a simplified yes/no acceptability test for sonic booms of varying overpressures and rise-times. Using Equation 2 herein and the matrix of rise-times and overpressures used in this test, the noise levels of the sonic booms were established and are presented in Table 1B. The acceptability for each combination of $\Delta P/\tau$ with its resulting perceived level, PLdB established by Equation 2 are contained in Table 1A. The acceptability of the various perceived levels based on this computation is presented graphically in Figure 4.

From an average curve (Figure 5) established by the test data and Equation 2 to determine the perveived level, a sonic boom level of 108 PLdB was acceptable to 75 percent of the subjects tested and a sonic boom of 100 PLdB was acceptable to 95 percent of the subjects. A favorable comparison between the acceptability of various perceived levels of sonic boom and aircraft flyover noise together with several category scales of acceptability intrusiveness and noisiness is shown in Figure 6.

The validity of the predictive Equations (2), (3) and (4) for sonic booms having acceptable perceived levels is borne out by the objective test data presented in Table 1. The test data contained in Table 7 show that the acceptability of a sonic boom remained the same even if overpressure was doubled provided the rise time was also doubled. This shows the validity of the sonic boom index and Equation (2) or that the perceived level is indeed a function of $\Delta P/\tau$. This is also the rate of change of pressure in psf/sec; N/M^2/sec or uB/sec. For example: A sonic boom with an overpressure of 1.5 psf and rise time of .004 second, or a rate of on-set of 375 pounds per second, has a

A) ACCEPTABILITY (%)

PSF \ Rise Time	.0016	.004	.008	.011
0.75	48	97	98	98
1.5	35	88	96	97
2.25	26	80	93	94
3.0	24	69	88	87

B) PERCEIVED LEVEL (PLdB)

PSF \ Rise Time	.0016	.004	.008	.011
0.75	108.4	100.5	94.5	91.7
1.5	114.4	106.5	100.5	97.7
2.25	117.9	110.0	104.	101.2
3.0	120.4	112.5	106.5	103.7

TABLE 1. Sonic Boom Acceptability and Perceived Level (PLdB) Variation With Overpressure And Rise Time.

perceived level estimated by Equation (2) of 106.5 PLdB. This sonic boom was found acceptable by 88 percent of the subjects exposed to this type signature. When the overpressure was doubled to 3.0 psf and the rise time increased to .008 seconds or maintaining a rate of onset of 375 pounds per second, a perceived level also estimated by Equation (2) of 106.5 PLdB, this signature was also found acceptable to 88 percent of the subjects. The same is true of the sonic booms having $\Delta P/\tau$ of 0.75/.004 and 1.5/.008 or a rate of onset of 187.5 pounds per second, both having a perceived level estimated by Equation (2) as 100.5 PLdB. Sonic Booms having these characteristics were found to be acceptable by 97 and 96 percent of the subjects exposed to them.

Further verification of the validity of Equation (2) is presented in Figure 2 which shows the close agreement within 1 or 2 PLdB with the loudness prediction theory of Zepler and Harel (Ref. 3) as modified by Pease (Ref. 20).

Table 1 also shows that subjective doubling of the perceived level also occurs at least in the acceptable range every 6 PLdB. The slope of Equation (2) is, therefore, verified as being 20 Log_{10} as the log of a doubling is 0.3 and 20 x 0.3 is 6 PLdB. The intercept of Equation (2) is still dependent on the Edwards experimental comparison with aircraft flyover noise. It should be revalidated in a similar test situation.

How simulated sonic booms in this test compared subjectively with actual sonic booms is unknown. Presently a similar experiment with different sonic boom simulation equipment but using similar methods of rating the sonic boom perceived levels as developed herein is being conducted by FAA.

However, taking these facts into consideration, it is shown that:

1. Rise time and overpressure are both important parameters in determining the perceived level of a sonic boom.

2. Sonic booms do have predictable perceived levels which can be altered by varying either or both the rise time and overpressure.

3. The ability to vary rise time and overpressure by aerodynamic design and by aircraft operations creates a potential design window for civilian supersonic aircraft. This design

window is based on the ability to determine the acceptable boom level and then placing constraints on the corresponding overpressure and rise time values (Figure 7).

Once acceptable perceived levels are determined and the ultimate combinations of overpressure and rise time are determined, the probability of glass breakage due to overpressure alone (Ref. 12) completes the present definition of the potential design window for supersonic overflight of populated areas. The rise time of the sonic boom overpressure in relation to glass breakage prediction is not significant as overpressure alone is the key prediction variable (Ref. 12). For example; a sonic boom having a 2 psf overpressure striking a plate glass window in good condition head-on having an area of 105 square feet (15' x 7') and ¼ inch thick has a 99.98% chance of not being damaged. For 3 psf the odds are 99.85%. At 4 psf the odds are 99.6% and at 5 psf the odds are 99% that no damage will occur.

For smaller windows the odds are even better that they will not break. In addition sonic booms do not always strike head-on and the odds are better as a function of the cosine of the flight path angle to the head-on or zero angle. For this reason the potential design window for supersonic aircraft (Figure 6) includes overpressures as high as 5 psf. The combinations of overpressure and rise time to the right of the 100 PLdB line are those found acceptable to 95% or more of the test subjects.

Although there is still no way at present to completely silence the sonic boom except by flying at speeds below Mach cut-off, reduction of the sonic boom perceived level (PLdB) is possible by reduction of the sonic boom index ($\Delta P/\tau$) or rate of onset of overpressure. Research (Ref. 13) has already shown that the overpressure of the sonic boom is controlled by parameters such as: altitude, weight, speed (when operating in the lower Mach number regimes), shape of the airplane, and the terrain over which the aircraft passes. Currently, the length of the aircraft has been shown (Ref. 18) to be a promising design parameter which increases sonic boom rise time. Although the aircraft lengths required to assure a significant rise time are apparently large, the need for better understanding by the supersonic aircraft designer of rise time's importance is warranted.

Operationally it is possible to increase the sonic boom rise time by increasing the altitude above and the lateral distance to populated areas thereby decreasing the perceived level (PLdB) of the sonic boom. The calculated variation of perceived level with

altitude and lateral distance is shown in FIGURES 8 and 9 based on the variation of use time obtained from reference 10.

Using the (SR-71) overpressure/rise time data of Reference 10, the sonic boom perceived levels (PLdB) versus altitude were calculated for the winter and summer by employing Equation 2. In addition, the acceptability of the sonic boom perceived levels calculated herein and presented in Figures 3 and 4 are included for easy reference in Figure 10. It can be readily seen that almost all of the sonic booms are at perceived levels that were acceptable to 50 percent of the subjects.

The variation of perceived level of sonic booms generated by SR-71 aircraft operations at approximately 70,000 feet and Mach 3.0 ranges from a high of 115 PLdB to a low of 80 PLdB with an average of 95 PLdB.

The average or mean perceived level of sonic booms generated by SR-71 aircraft operations also varies with altitude being around 115 PLdB at 20,000 feet, 100 PLdB at 50, 000, and 95 PLdB at 70,000 feet. The distribution of PLdB around these mean perceived levels is similar to that determined at 70,000 feet.

Studies at White Sands, New Mexico have shown that for 1,494 sonic booms with scheduled overpressures from 1.9 to 19 psf, the natural environment had more of a damaging effect on glass and structures than the sonic boom (Ref. 14).

For the overpressure, associated with civil supersonic flight, sonic boom research has also shown that there is no damaging effects on wildlife and farm animals such as cows, chickens, mink, and fish (Ref. 15, 16, 17).

IV. SUMMARY AND CONCLUSIONS

A potential design window for supersonic overflight based on the perceived level (PLdB) and glass damage probability of sonic booms is outlined.

The evaluation of a simple operational method of estimating the perceived level (PLdB) of sonic booms:

$$\text{PLdB} = 55 + 20 \log_{10} \frac{\Delta P \text{ (psf)}}{\tau \text{ (sec)}}$$

is discussed and compared with the Fourier transform computer program calculations of Pease based on the theory of Zepler and Harel. The resulting estimated perceived levels are in good agreement i.e., within 1 to 2 PLdB of each other in the important potential certification or design window that is in the 90 to 100 PLdB range. These perceived levels are shown to be acceptable to 95 to 100 percent of the people exposed to them.

The levels estimated using the method of May vary considerably with the levels determined by the other 2 methods, previously discussed.

There are two areas that need additional work:

1. Psychophysical studies regarding human acceptability of the sonic boom perceived level especially during actual supersonic flight conditions.

2. Aerodynamic studies aimed at reducing overpressure/rise time or rate of onset of sonic boom maximum peak overpressure with a view to reducing the perceived level PLdB of sonic booms to acceptable levels.

The ultimate goal is to maximize compatability between the aviation system and the environment in which it operates. If acceptability standards for sonic booms based on perceived levels, PLdB, are set, then Transonic, Supersonic, and Hypersonic Aerospace vehicle research and development will be accelerated and the road block to progress in commercial supersonic aviation presented by the sonic boom will eventually be overcome.

REFERENCES

1. Federal Register, April 16, 1970 (35FR6189) Notice 70-16.

2. Federal Register, March 28, 1973 (38FR8051) Part 91.

3. Zepler E.E. and Harel, J.R.P., Sound Vibrations (1965), pp 249-256, "The Loudness of Sonic Booms and Other Impulsive Sounds".

4. Higgins, T. H., Memorandum To Supersonic Transport Development Office, SS-230, February 21, 1968.

5. Higgins, T. H., Staff Study on "Human Reaction To The Sonic Boom", April 23, 1968.

6. Higgins, T. H. Staff Study on "Structural Reaction To The Sonic Boom", April 23, 1968.

7. Higgins, T. H., Staff Study on "Minimization of the Boom Index Thru Design", May 23, 1968.

8. Kryter, K.O.; Johnson, P.J.; Young, J.R.; "Sonic Boom Experiments At Edwards, Air Force Base", Interim Report, July 18, 1967, Annex B.

9. Stevens, S. S., "Perceived Level of Noise Mark VII and Deceibels(E)", Journal Of Acoustical Society Of America Vol. 51, No. 2 (Part 2), February 1972.

10. Maglieri, Domenic J.; Huckel, Vera; and Henderson, Herbert R. Henderson: "Sonic Boom Measurements For SR-71 Aircraft Operating At Mach Numbers To 3.0 and Altitudes to 24384 Meters. NASA TN D-6823.

11. Man-Acoustics and Noise Data, Personal Communication.

12. Hershey, Robert L. and Higgins, T. H.: "Statistical Prediction Model For Glass Breakage From Nominal Sonic Boom loads FAA-RD-73-79.

13. Whitham, G. B.: "The Flow Pattern Of A Supersonic Projectile," Communication Pure Applied Mathematic, Vol. 5, 1952, pp. 301-348.

14. Wiggins, J. H., Jr.: "Sonic Boom and Natural Deterioration Effects On Building: "WhiteSands, New Mexico; Structure Resurvey", FAA-RD-72-25.

15. Heineman, J. M., "Effects Of Sonic Booms On The Hatchability Of Chicken Eggs and Other Studies Of Aircraft-Generated Noise Effects On Animals". Paper presented to symp on Extra-Auditory Effects of Audible Sound, Ann. Meeting, America Associate for the Advancement of Science (December 29, 1969).

16. U. S. Department of Agriculture, "An Interdisciplanary Study of the Effects of Real and Simulated Sonic Booms On Farm-Raised Mink (Mustela Vison) FAA-EQ-72-2.

17. Rucker, Robert R., "Effects of Sonic Boom On Fish", FAA-RD-73-29.

18. McLean, F. Edward; Carlson, Harry W.; and Hunton, Lynn W., "Sonic Boom Characteristics of Proposed Supersonic and Hypersonic Airplanes, NASA TN D-3587.

19. May, D.N., "The loudness of Sonic Booms Heard Outdoors As Simple Functions of Overpressure and Rise-Time". Journal of Sound and Vibration, Volume 18, No. 1, September 8, 1971, pp. 31-43.

20. Pease, C.B., "A Note On The Spectrum Analysis Of Transients And The Loudness Of Sonic Bangs". The Journal of Sound and Vibration, Volume 6, No. 3, 1967, pp. 310-314.

LIST OF SYMBOLS

k	Constant
PLdB	Perceived Level (decibel)
PNdB	Perceived Noise (decibel)
ΔP	Change in pressure, overpressure (pounds/foot^2)
τ	Onset time of peak overpressure, rise time (sec, msec)

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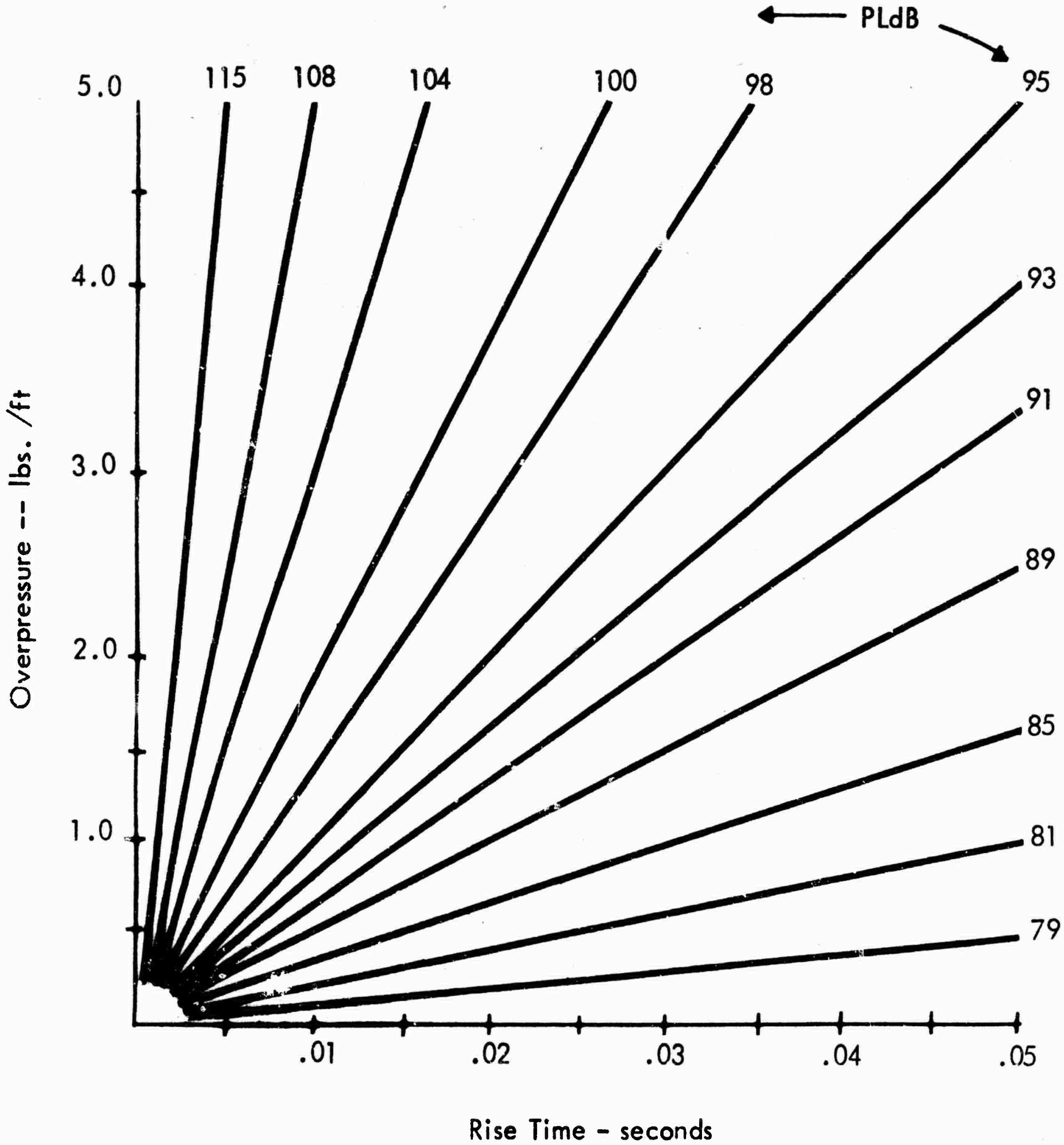


Chart employs the equation: $\text{PLdB}=55+20 \log_{10} \frac{\Delta P(\text{psf})}{\tau(\text{SEC})}$

FIGURE 1. Relationship of Overpressure and rise-time to the Sonic Boom Perceived Level, PLdB.

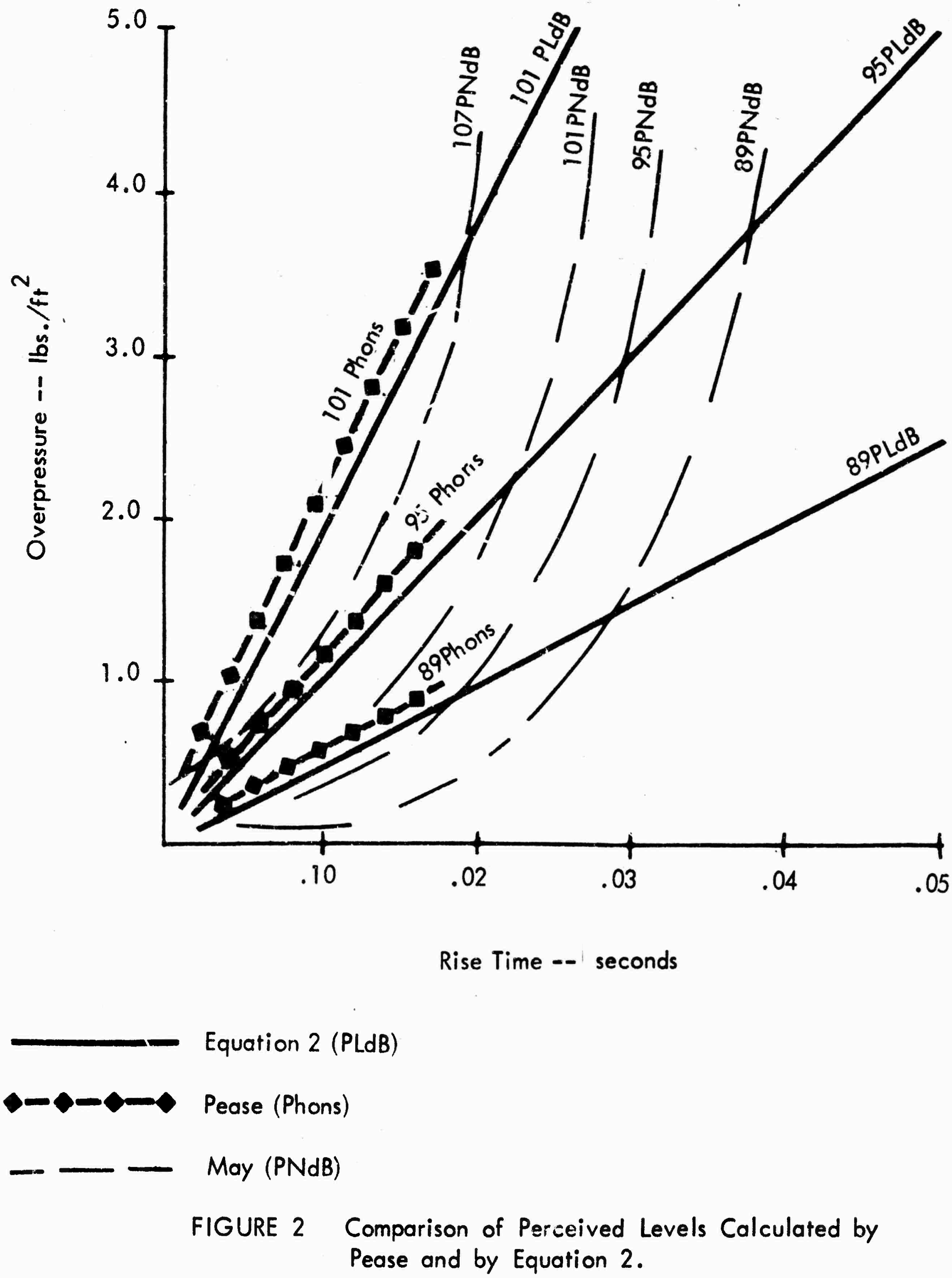
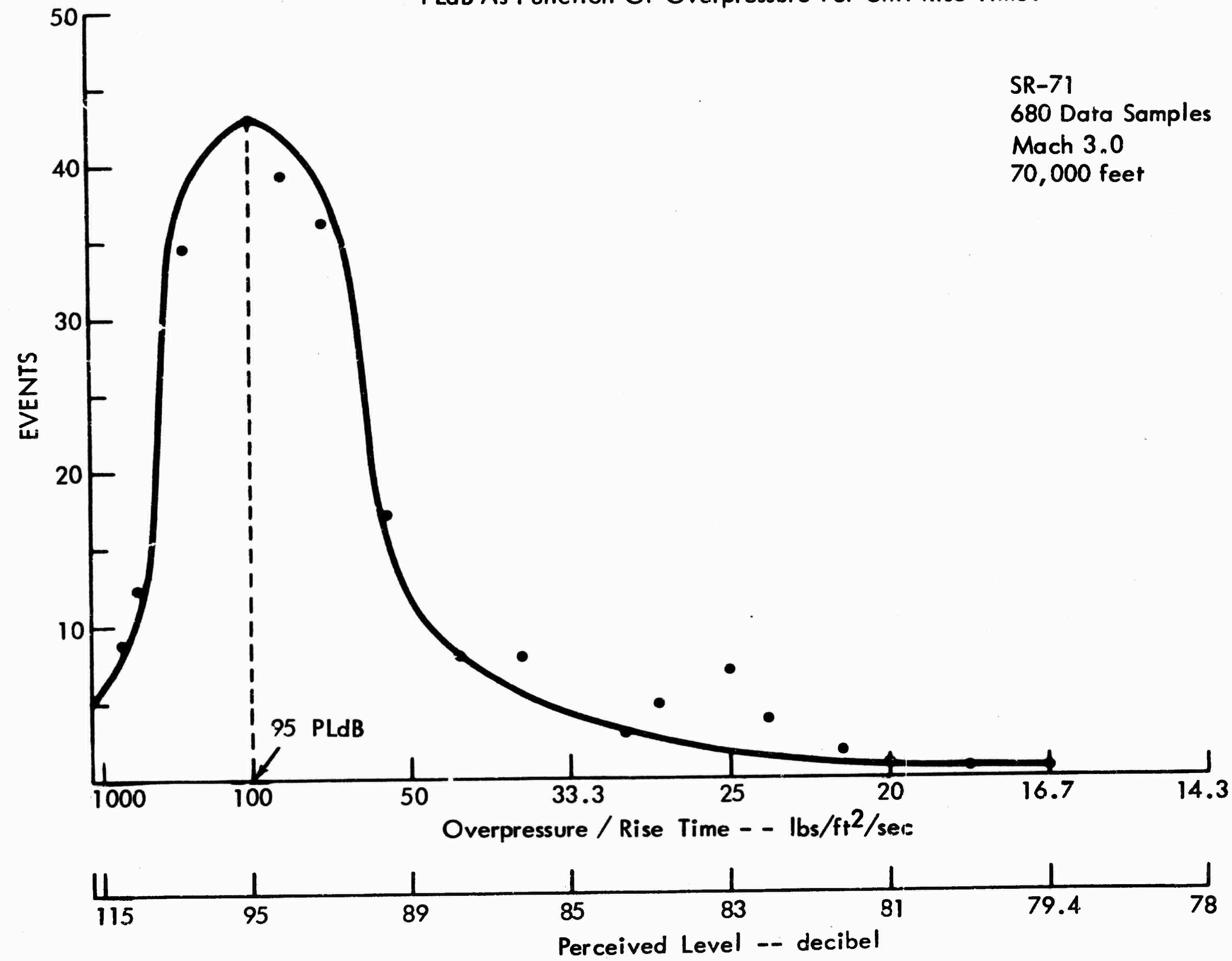


FIGURE 2 Comparison of Perceived Levels Calculated by Pease and by Equation 2.

FIGURE 3. Frequency Distribution of SR-71 Aircraft Perceived Levels PLdB As Function Of Overpressure Per Unit Rise Time.



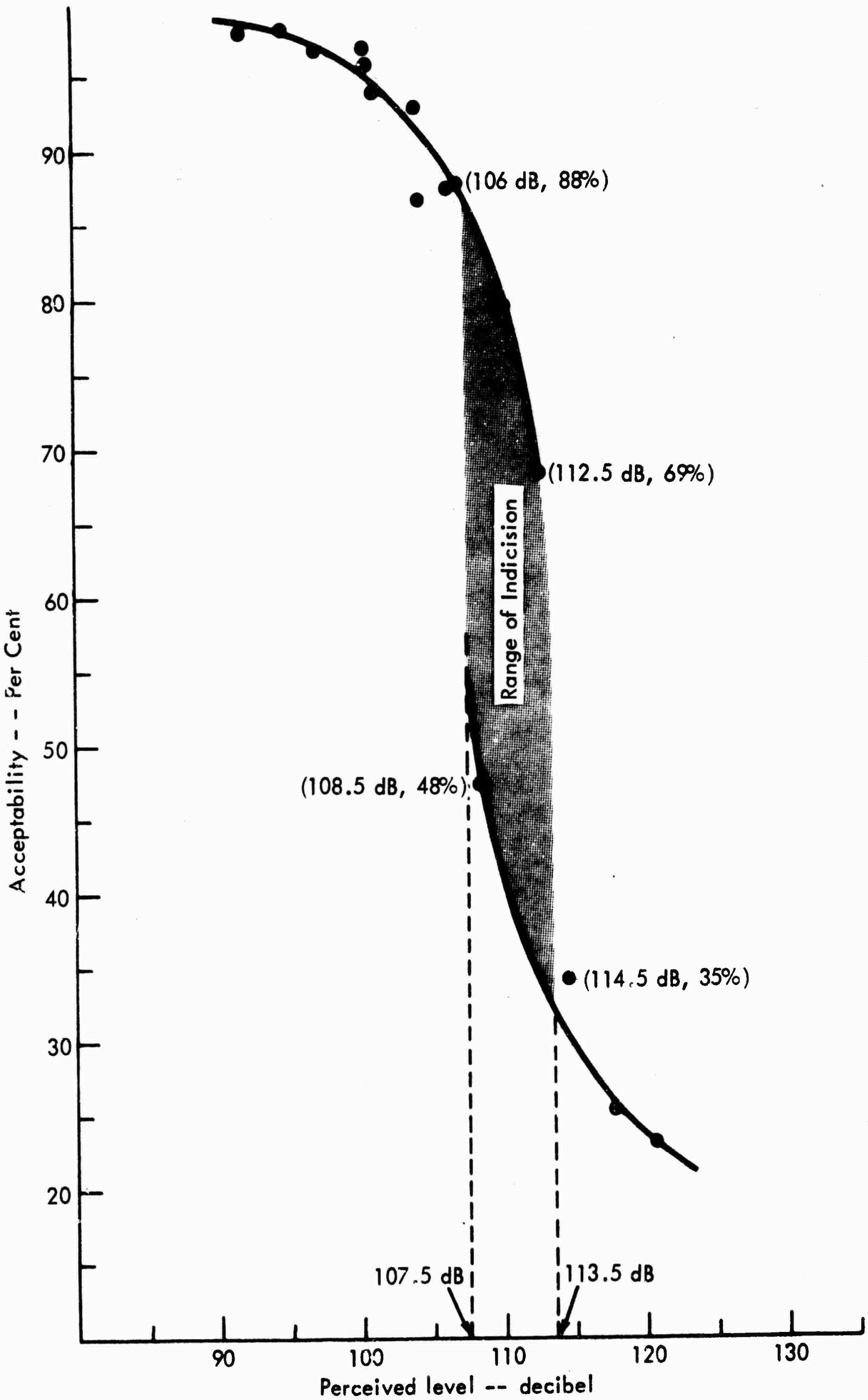


FIGURE 4. Acceptability Of Sonic Booms According To Their Perceived Level, PLdB.

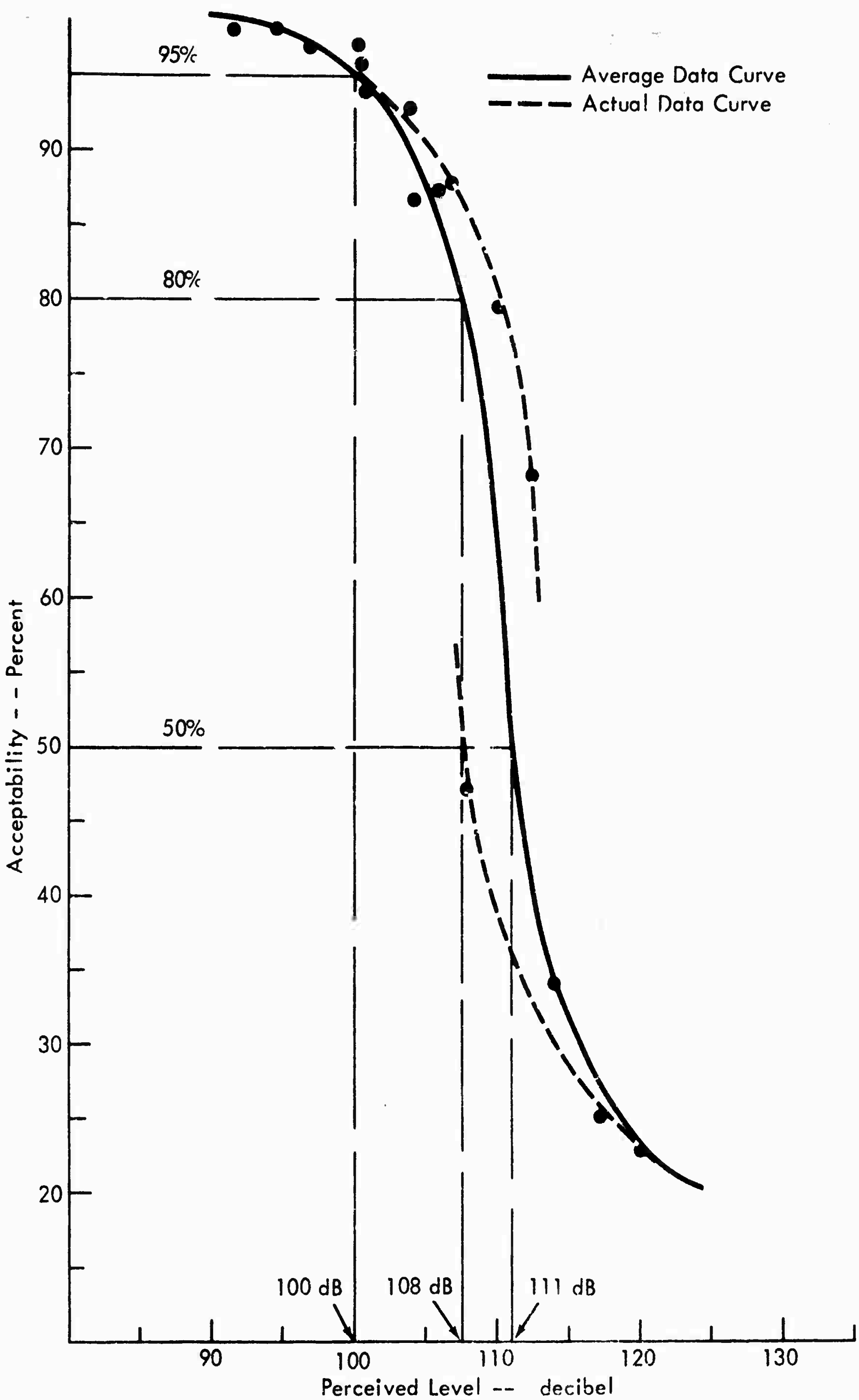


FIGURE 5. Sonic Boom Acceptability (Average Data) Curve

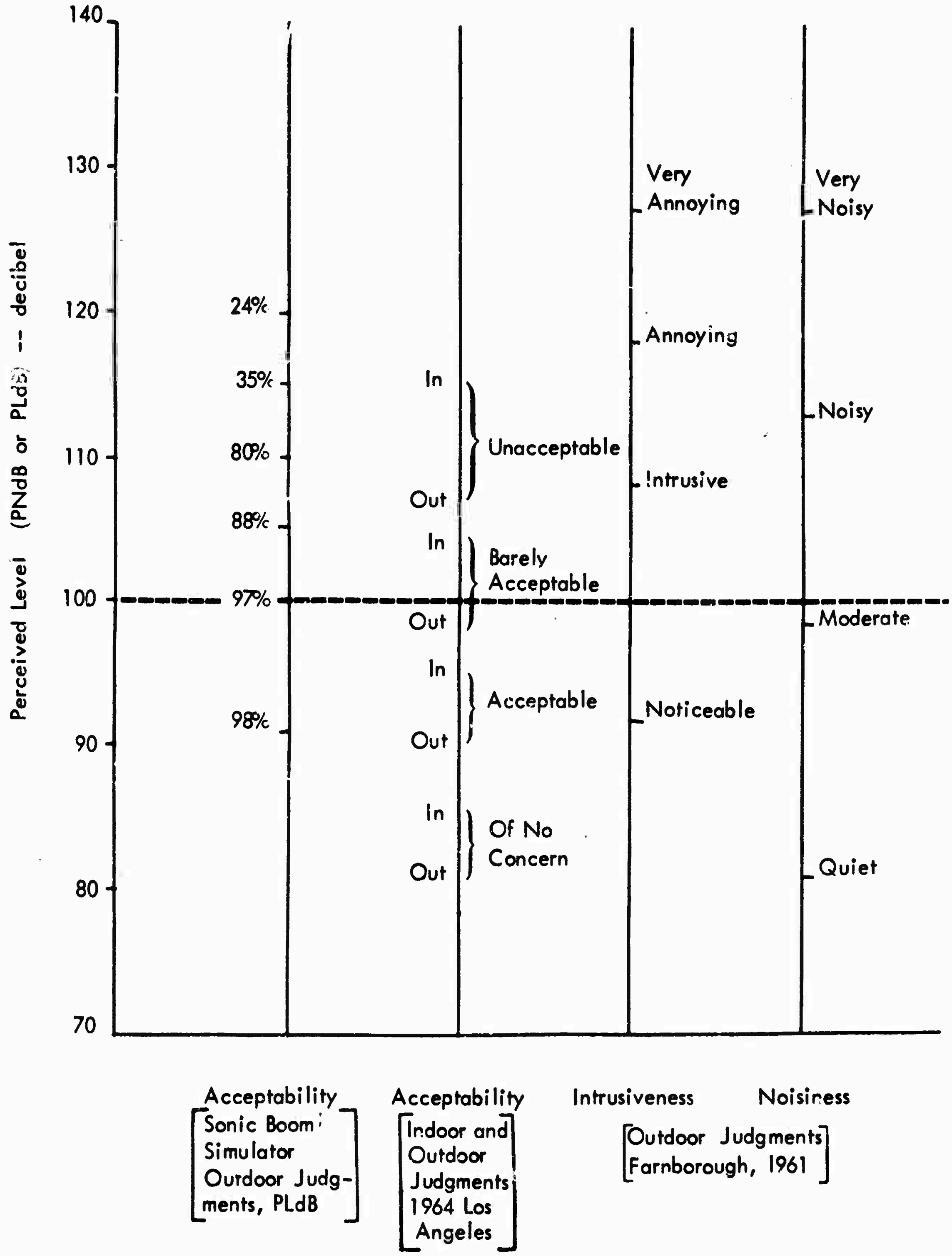


FIGURE 6. Comparison Between The Acceptability Of Various Perceived Levels Of Sonic Booms And Aircraft Flyover Noise Together With Several Category Scales Of Acceptability, Intrusiveness And Noisiness.

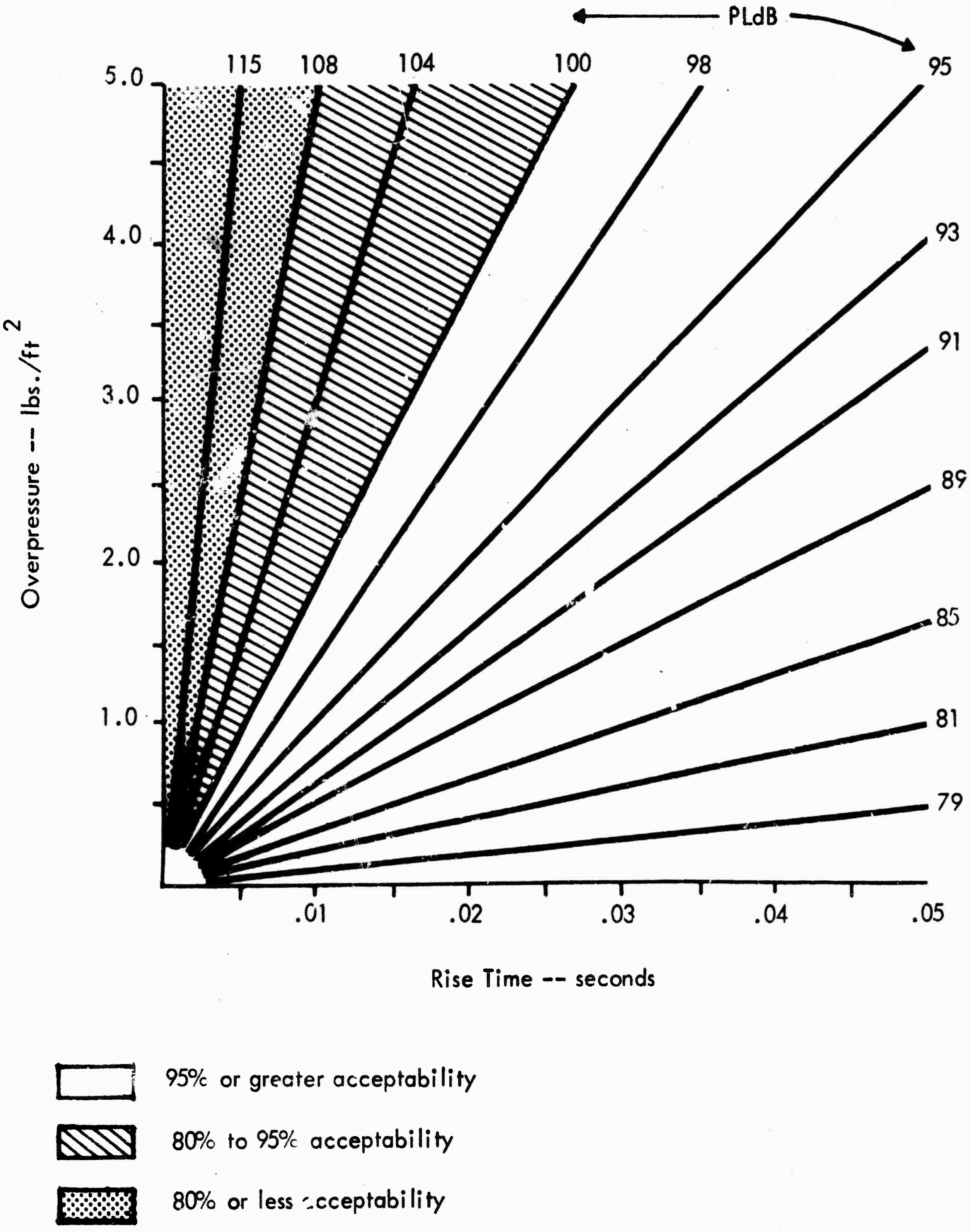


FIGURE 7. Potential Supersonic Aircraft Design Window (The Acceptability Of Various Sonic Boom Overpressure/Rise Time Combinations And Their Perceived Level.)

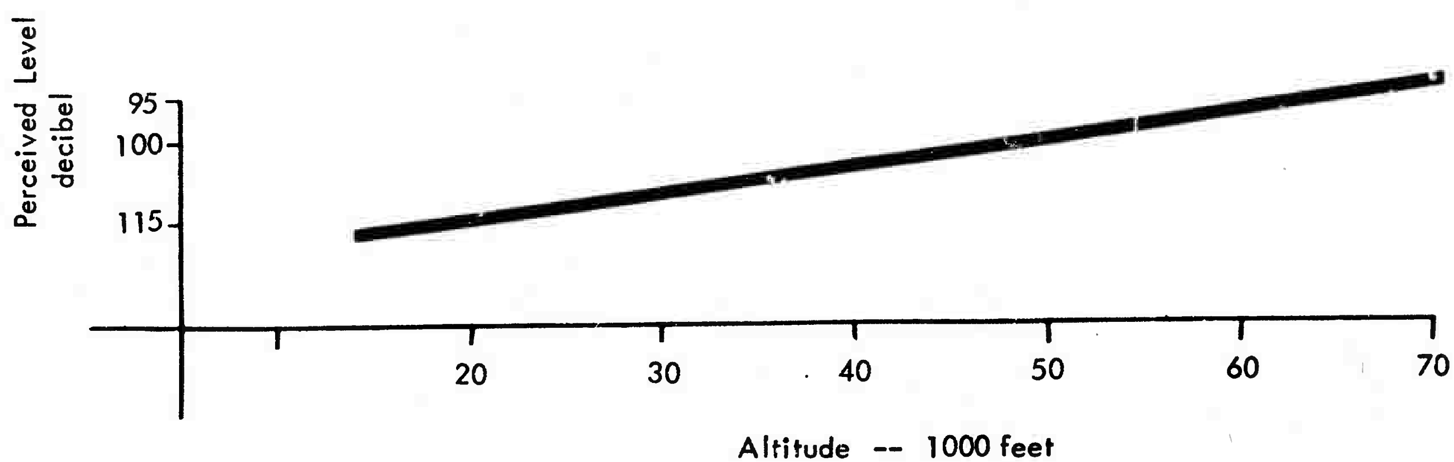


FIGURE 8. SR-71 Aircraft Variation Of Sonic Boom Perceived Level With Altitude.

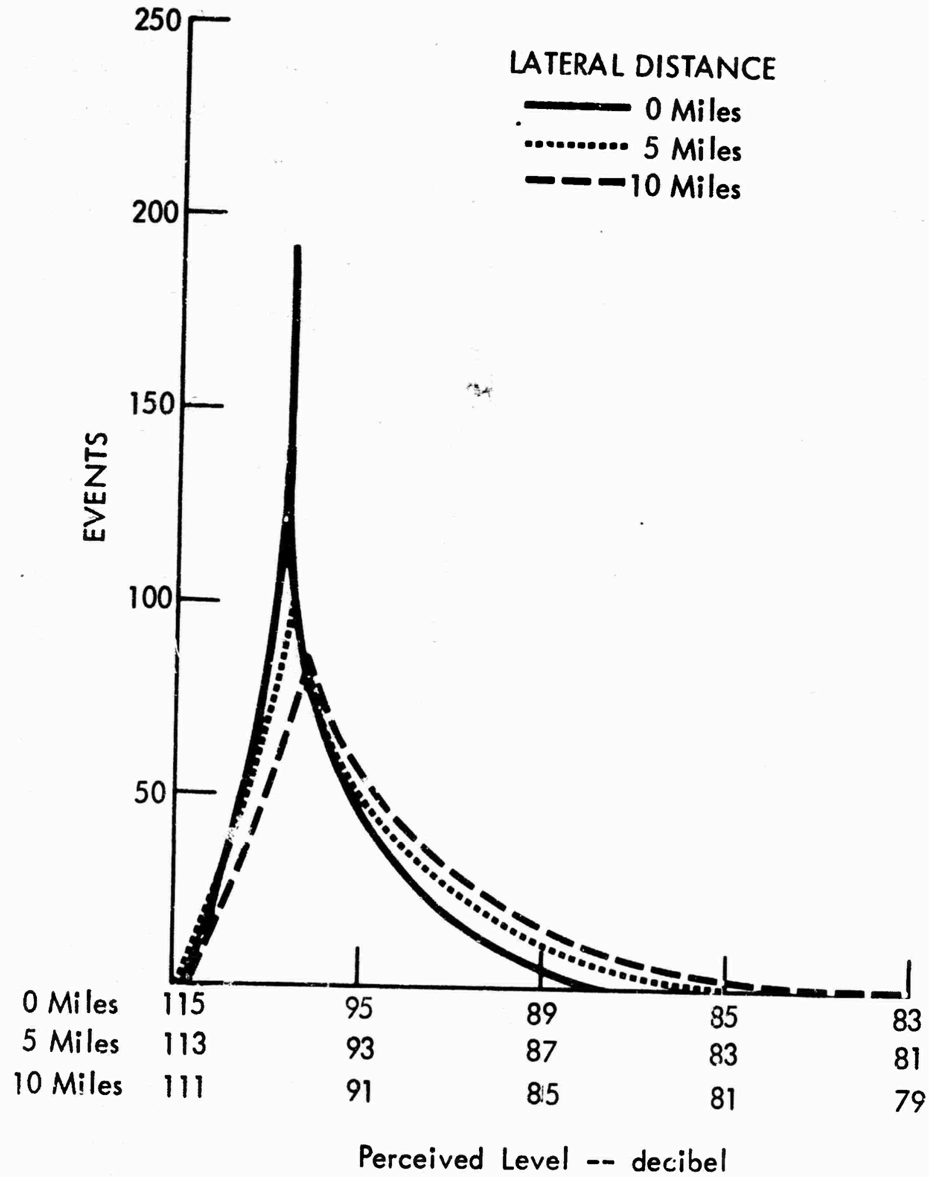
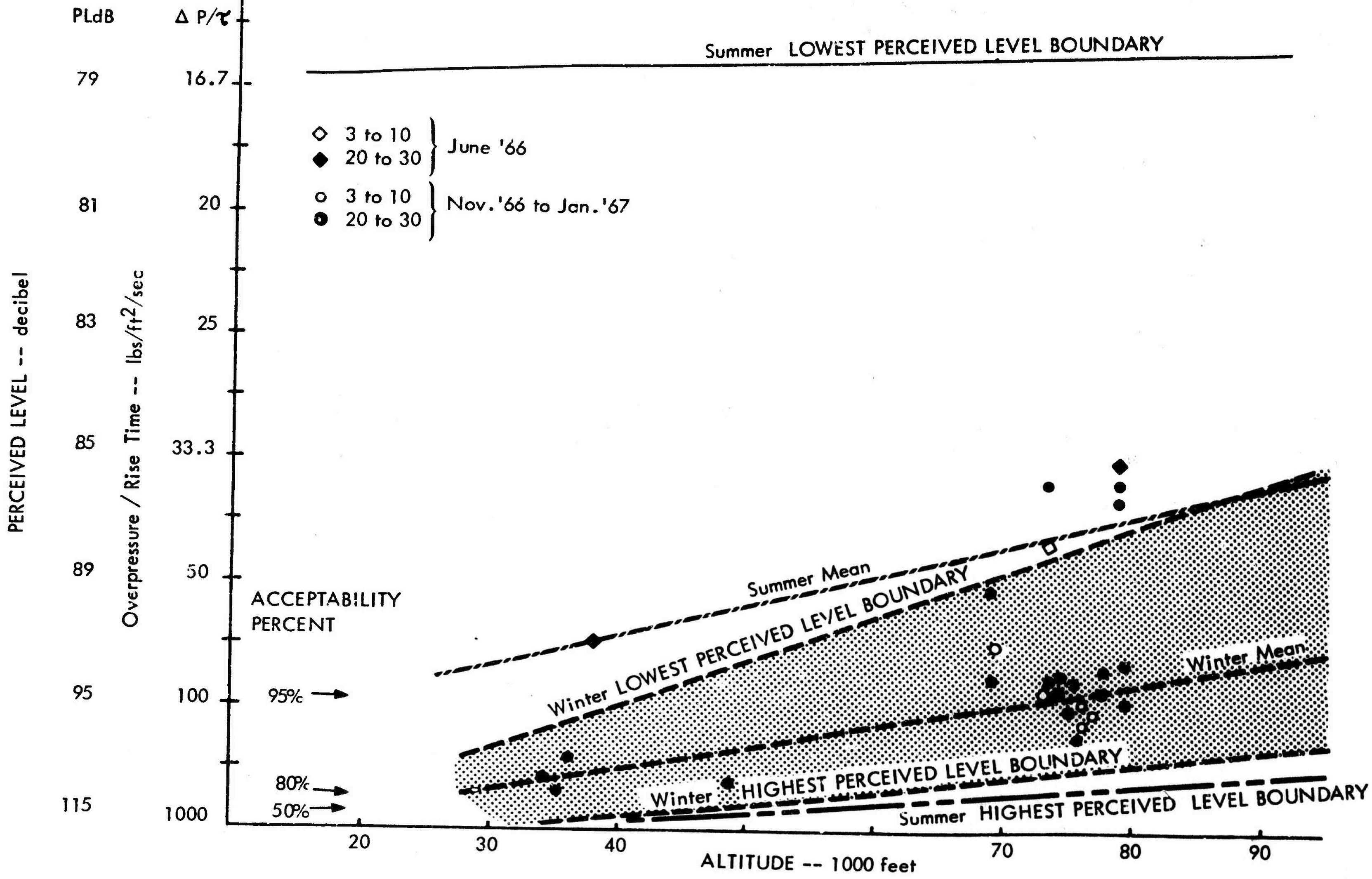


FIGURE 9. SR-71 Aircraft Variation of Sonic Boom Perceived Level With Lateral Distance.

FIGURE 10. Variation Of Sonic Boom Perceived Level, (PLdB) With Altitude During Winter And Summer.



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